DRAFT -- To be published in DMT'08 Proceedings
(see http://ngmdb.usgs.gov/Info/dmt/)

Digital Map Production and Publication at the Geological Survey of Alabama

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INTRODUCTION

The Geological Survey of Alabama (GSA) is currently conducting geologic mapping at 1:24,000 scale (7.5-minute topographic quadrangle maps) in conjunction with the U.S. Geological Survey's (USGS) STATEMAP program. On average, the GSA is mapping three quadrangles each field season. These maps are compiled digitally, and a paper copy is completed and submitted to the USGS as a contract deliverable map. The map then goes through an internal GSA review and is published as a Quadrangle Series Map that includes a map report. The GSA has published 50 Quadrangle Series Maps that were supported in part by the STATEMAP program and, previously, by the Tennessee Valley Authority. The process of creating and updating digital databases for all of these quadrangles is ongoing.

Many of these maps have been either compiled in a digital format or converted into a digital format. There are two processes running concurrently: (1) the creation of new geologic maps and digital databases, and (2) the updating of previously published maps into a current digital format. Currently, the GSA is releasing data in three formats. The first is a database package using Environmental Systems Research Institute (ESRI)-supported geodatabases. The second is a shapefile package, with most of the same available data; these files can be used with most GIS software. The final package includes a PDF of the map and map explanation. Metadata are written for all of the digital data that the GSA has created. The release of geodatabases, shapefiles, and PDF files via the GSA website began in 2007. The only part of the publication not released within these three packages is the map report, which is available by purchase in the GSA Publications Sales office. The goal is to release the digital files of all of the previous and future STATEMAP quadrangles to the public.

COLLECTION OF DATA

Field mapping is still dominantly rooted in traditional (nondigital) data collection techniques. The geologic mappers at the GSA take a paper copy of the quadrangle into the field and collect data points using a hand-held GPS, Brunton compass, and barometric altimeter. Locations of observations are plotted on the field sheet (Figure 1) and the observations are written in a field notebook; and then in the office the location points commonly are transcribed to a paper copy of the map. Sometimes, rather than transcribing to a paper copy in the office, the observations are directly entered into a GIS format as points (Figures 2 and 3).

Recently, a handheld Trimble GeoExplorer XM has been purchased to collect digital data in the field. This unit is being tested for the possible collection of more detailed and complex information, and for integration of digital data in the field. Currently, observation points are collected in this device with ArcPad 7.1 and then compiled in the office into an ArcGIS database. These observation points coincide with those collected and transcribed on the hardcopy map sheet.

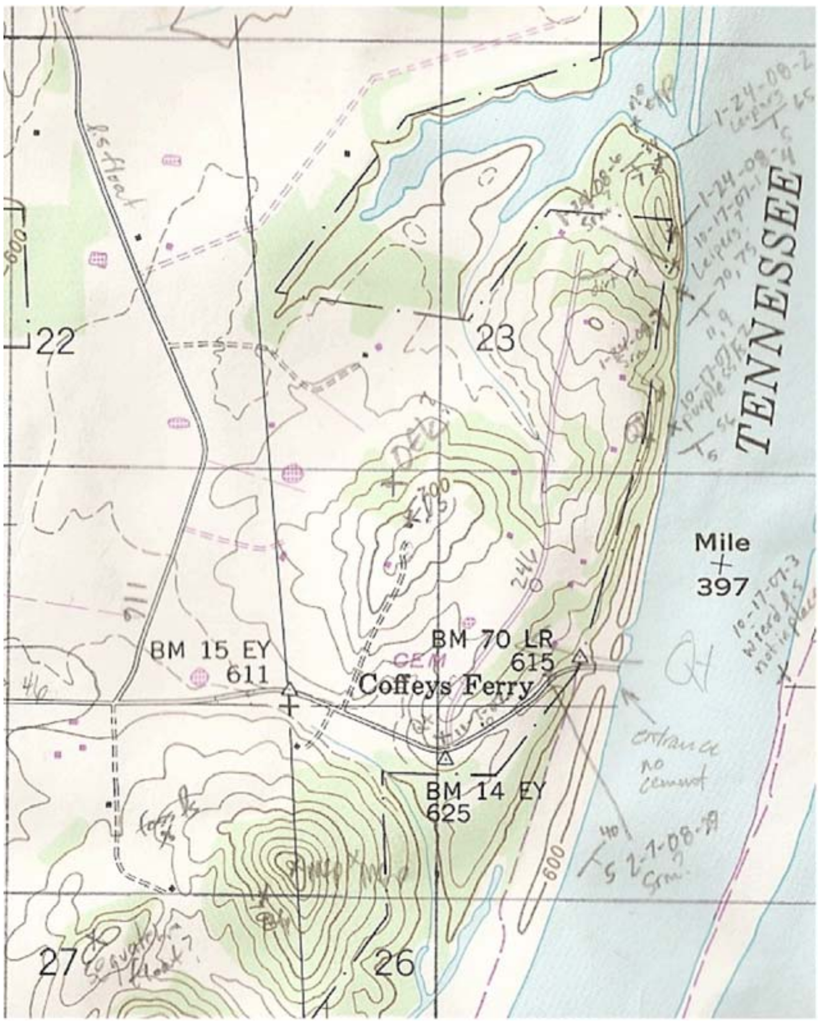

Figure 1. Field sheet with locations.

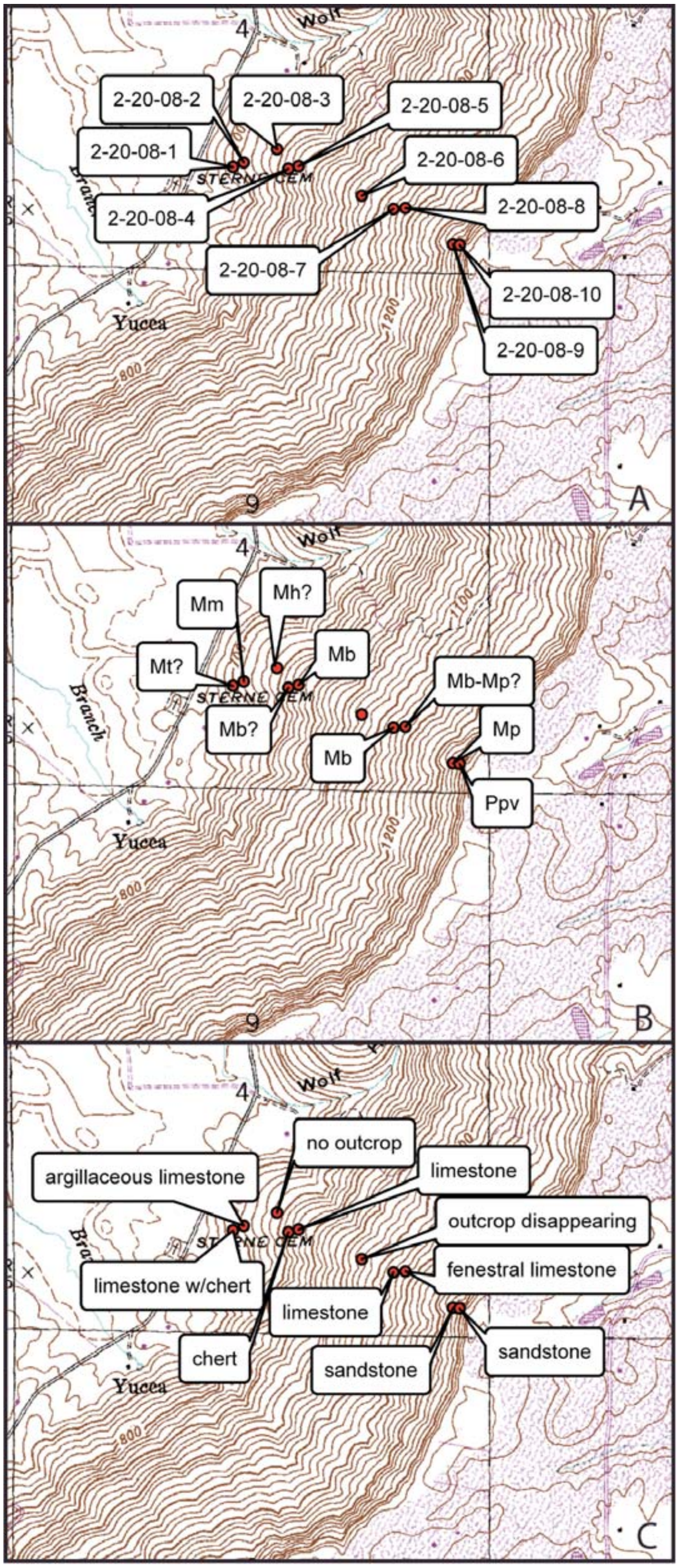

Figure 2. Three labeling schemes used to help make interpretations of geologic units and contacts. A. Observation points, date used as identifier. B. Field-interpreted geologic units. C. Lithology of rocks at each observation point.

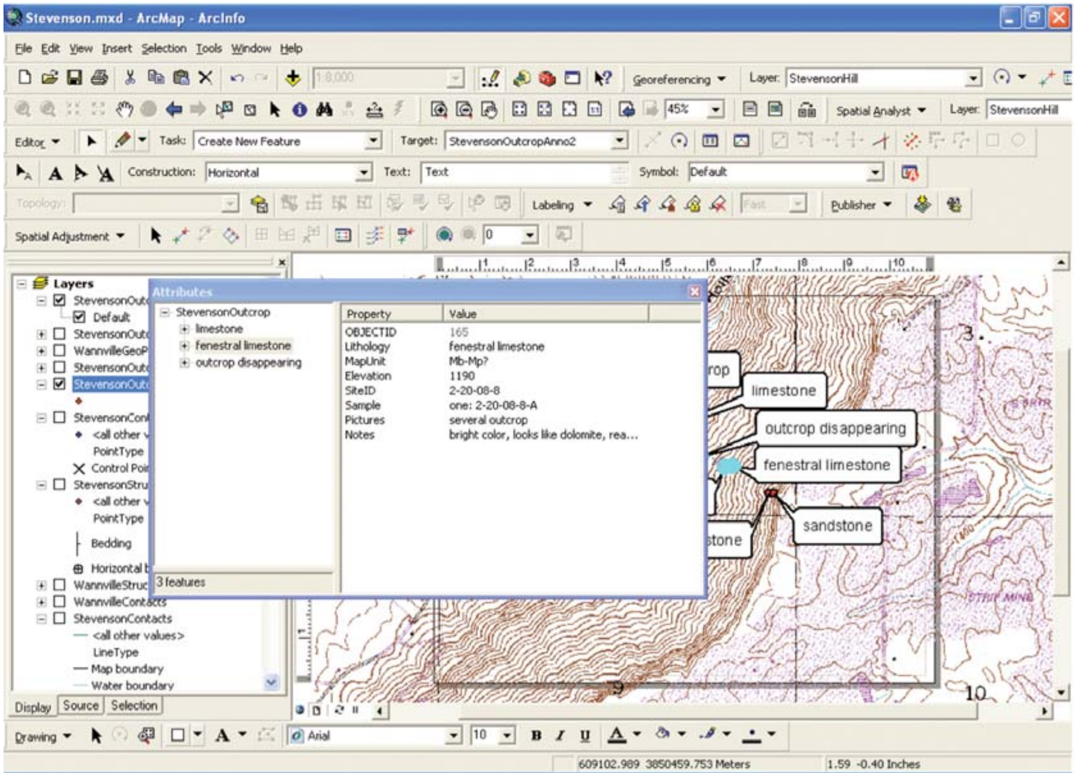

Figure 3. Attributes entered from field observations. At each location the lithology, probable geologic unit, altitude (from altimeter), sample ID, samples and/or pictures taken, and notes associated with that location are recorded.

COMPILATION OF DATA

The field data are compiled by first creating in ArcCatalog a geodatabase with the desired feature classes and attributes in (Table 1). Then, using a georeferenced USGS topographic map as a basemap, data points from field observations are entered into the database as a map of outcrops (Figure 2). For display purposes the background colors (green and white) of the topographic tiff image are turned to a null value; later, when the map is being prepared for publication, the base is set to a desired transparency level overlain on the geology polygons layer. Along with the outcrop points, structural points and control points are entered where these observations were taken. At present, the outcrop points are only being used in the map construction process and are not being released with the final digital files. The next step is the construction of geologic contacts and structural lines. Two methods have been used. The first entails drawing the lines on a clean paper copy of the topographic base. The map is then scanned on a large format scanner, georeferenced in ArcMap, and digitized from this scan. The other method is to heads-up digitize on the screen in ArcMap using the outcrop map as a guide. When available, hydrologic lines are downloaded from various sites and used as a control for mapping. Quaternary alluvium contacts are drawn using both field observations and county soil surveys (Figure 4). Polygons of geologic units are then constructed from the lines.

Table 1. Features, layers, and data currently used in GSA maps.

LAYERS	FEATURES	DATA
Points	***Structural Points***	Type of point, strike and dip values
	Control Points	Locations where contacts between two units are identified
Lines	***Contacts***	Geologic contacts, faults, and water boundaries
	Structural Lines	Anticlines and synclines
	Cross Section	Cross sections
Polygons	***Geology Polygons***[1]	Geologic Units (map unit name) Map unit abbreviations Age
Annotation	***Contacts*** ***Structural Lines***	Full name of feature (most commonly, faults and structural lines)
	Structural Points	Dip values on structural points
	Geology Polygons	Map unit abbreviations

[1] Unit descriptions are found in the metadata.

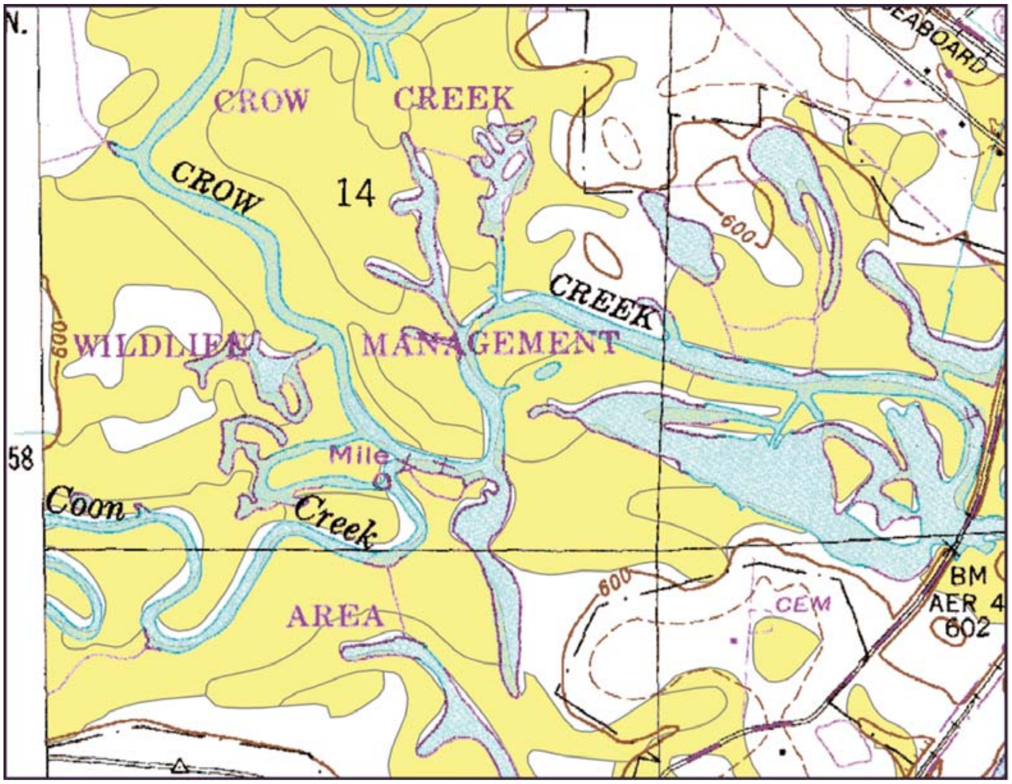

Figure 4. Soil data from county surveys. Alluvial soils are used to constrain location of Quaternary alluvium deposits.

CONSTRUCTION OF MAP AND DATABASE

Once the field observations and interpretations are entered, the database is populated with the desired attribute data (Table 1 and Figures 5, 6, 7, 8). After the population of all features is complete, feature-linked annotation is constructed in ArcMap as necessary. Commonly, annotation includes the dip numbers for the structural points, map units for the geologic polygons, and names for specified lines such as names on faults and structural cross section lines. The feature-linked annotation in ArcMap allows for easy movement of the annotation to desired positions on the map. Additionally, when changes are made to attributes, the feature-linked annotation is automatically updated, reducing the chance for label errors on the map.

Attributes of ConcordGeologyPolygons

MapUnit	Age	Unit
Oc	Middle Ordovician	Oc, Chickamauga Limestone
Qal	Quaternary	Qal, Alluvium
Srm	Lower and Upper Silurian	Srm, Red Mountain Formation
Oc	Middle Ordovician	Oc, Chickamauga Limestone
Mh	Upper Mississippian	Mh, Hartselle Sandstone
Srm	Lower and Upper Silurian	Srm, Red Mountain Formation
Mpm	Upper Mississippian	Mpm, Pride Mountain Formation
Mfb	Upper Mississippian	Mfb, Floyd Shale and Bangor Limestone undifferentiated
Mtfpm	Lower and Upper Mississippian	Mtfpm, Tuscumbia Limestone, Fort Payne Chert, and Maury Formation undifferentiated
Mh	Upper Mississippian	Mh, Hartselle Sandstone
Srm	Lower and Upper Silurian	Srm, Red Mountain Formation
Mtfpm	Lower and Upper Mississippian	Mtfpm, Tuscumbia Limestone, Fort Payne Chert, and Maury Formation undifferentiated
Mh	Upper Mississippian	Mh, Hartselle Sandstone
Mtfpm	Lower and Upper Mississippian	Mtfpm, Tuscumbia Limestone, Fort Payne Chert, and Maury Formation undifferentiated
Mfb	Upper Mississippian	Mfb, Floyd Shale and Bangor Limestone undifferentiated

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Figure 5. Attribute table for geologic units. Attributes include map unit abbreviation, unit name, and age.

Attributes of ConcordContacts

OBJECTID *	SHAPE *	SHAPE_Length	LineType	Name
85	Polyline	2861.975242	Thrust fault, very approximately located	<Null>
86	Polyline	2474.933569	Thrust fault, very approximately located	McAshan Mountain fault
87	Polyline	266.363656	Thrust fault, very approximately located	<Null>
88	Polyline	2525.316573	Thrust fault, very approximately located	Blue Creek fault
89	Polyline	53.964265	Thrust fault, very approximately located	<Null>
90	Polyline	1750.440877	Thrust fault, very approximately located	<Null>
91	Polyline	4024.349645	Thrust fault, very approximately located	<Null>
311	Polyline	60.055981	Contact, very approximately located	<Null>
314	Polyline	2467.697435	Contact, very approximately located	<Null>
269	Polyline	153.443002	Normal fault, very approximately located, R	<Null>
270	Polyline	360.716611	Normal fault, very approximately located	<Null>
271	Polyline	164.353344	Normal fault, very approximately located, R	<Null>
272	Polyline	144.068571	Normal fault, very approximately located	<Null>

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Figure 6. Attribute table for geologic contacts. Attributes include type of contact or fault, and name of feature, if any.

Attributes of ConcordStructureLines

SHAPE_Length	LineType	Name
679.958387	Fold axis, syncline, approximately located	Blue Creek syncline
944.787455	Fold axis, syncline, approximately located	Coalburg syncline
88.264874	Fold axis, syncline, approximately located, plungeW	<Null>
1466.090089	Fold axis, anticline, approximately located	Blue Creek anticline
1240.033436	Fold axis, anticline, approximately located	<Null>
164.69971	Fold axis, syncline, approximately located	<Null>
1454.690278	Fold axis, syncline, approximately located	<Null>
706.007273	Fold axis, syncline, approximately located	<Null>
132.728443	Fold axis, syncline, approximately located, plungeW	<Null>
1268.271767	Fold axis, syncline, approximately located	<Null>
175.616537	Fold axis, syncline, approximately located	<Null>
280.935536	Fold axis, anticline, approximately located	<Null>
263.32276	Fold axis, syncline, approximately located, marker	<Null>

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Figure 7. Attribute table for structural lines. Attributes include linetype of structural line and name of feature, if any.

Attributes of ConcordStructurePts

OBJECTID *	SHAPE *	PointType	Strike	DIP
143	Point	Bedding	30	82
144	Point	Overturned bedding	1	61
145	Point	Overturned bedding	340	69
146	Point	Bedding	36	63
147	Point	Bedding	68	42
148	Point	Overturned bedding	25	28
149	Point	Overturned bedding	10	57
150	Point	Overturned bedding	39	74
151	Point	Overturned bedding	50	55
152	Point	Overturned bedding	28	52
153	Point	Overturned bedding	48	52
154	Point	Vertical bedding	30	90
155	Point	Bedding	30	9

Record: 0 Show: All Selected Records

Figure 8. Attribute table for structural points. Attributes include structural point type, strike (using 0-360 azimuth), and dip.

The attributes in the GSA database continue to evolve, and we are making efforts to integrate the North American Geologic Map Data Model (NADM). Currently, the following attributes are included in newly constructed GSA database layers (see also Table 1):

- *Geology Polygons* – Map unit (the map unit abbreviation), Unit (Name of geologic unit), and Age (see Figure 5)
- *Contacts, Cross Section and Structural Lines* – Line type and name (see Figures 6 and 7)
- *Structure Points* – Point type, Strike, and Dip (see Figure 8)
- *Control Points* – Point type, elevation (when available) and Geologic units (if necessary)

Construction of the cross section is still done by a primarily nondigital process. Until recently, only 30-meter DEMs were available in the current mapping area, which provide too coarse a topographic surface profile for some available cross-section building programs. The desired line is drawn on the map and the elevations are gleaned from the topographic base and transferred to a piece of graph paper to get the surface profile. The cross section is then drawn using structural observations and known or approximate thicknesses of units. After the cross section is completed by hand, it is scanned, drawn in Adobe Illustrator, and then added to the layout. Compiled 10-meter DEMs are now available for areas to be mapped in the upcoming year, and GSA is hoping to digitally generate a topographic surface profile using that data.

Metadata

Metadata are written within ArcCatalog for each feature class and then are exported in text (.txt) format. Similar information in each feature class (citation, distribution, etc.) is completed only once in ArcCatalog and then is copied and pasted into each feature class's metadata in Notepad. Metadata for each feature class are completed in Notepad and then are imported back into ArcCatalog for each feature class. Finally, metadata that include information from all feature classes are compiled in Notepad and then imported at the Geodatabase and Feature Dataset levels.

Overall, the objective to put most, if not all, of the data in the database is an ongoing process. The most important data that is only found in the metadata are the geologic unit descriptions (Figure 9). Preferably, these data would be in the GeologyPolygons feature class/shapefile, but a suitable presentation for the data is unknown. There is no word wrap feature in the attribute table, and users would have to scroll laterally through a single line to read the description.

Attribute:
Attribute_Label: **UNIT**
Attribute_Definition: **Stratigraphic Unit Description**
Attribute_Definition_Source: Author
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: **Qal, Alluvium**
Enumerated_Domain_Value_Definition: Unconsolidated sand, silt, clay, and angular to rounded chert gravel.
Enumerated_Domain:
Enumerated_Domain_Value: **Ppv, Pottsville Formation**
Enumerated_Domain_Value_Definition: Light-gray, medium- to coarse-grained, quartzose sandstone locally containing scattered to abundant well-rounded quartz pebbles; quartz pebbles and/or claystone conglomerate locally present. Interbeds and intervals of dark-gray shale and mudstone and wavy- to lenticular-bedded sandstone and shale locally present.
Enumerated_Domain:
Enumerated_Domain_Value: **Mp, Pennington Formation**
Enumerated_Domain_Value_Definition: Lower part dominated by light-greenish-gray to light-bluish-gray, conchoidally fractured dolomicrite containing nodules and stringers of dark-gray chert and thin interbeds of dark-gray and greenish-gray shale and mudstone. Middle part includes variably gray, bioclastic limestone; cherty, argillaceous limestone; limey dolomite; and dolomite containing intervals of maroon and olive-green mudstone. In the southern part of the quadrangle, the uppermost part consists of interbedded maroon and olive-green shale and mudstone. On Keel Mountain, the uppermost part is dark-gray shale, wavy- to lenticular-bedded sandstone and mudstone, ripple-laminated sandstone, and shaly coal.
Enumerated_Domain:
Enumerated_Domain_Value: **Mb, Bangor Limestone**
Enumerated_Domain_Value_Definition: Predominantly light- to locally dark-gray, bioclastic and oolitic limestone. Medium- to dark-gray shale containing thin to discontinuous interbeds of medium-dark-gray, fossiliferous limestone common at base. Lower part includes medium-gray peloidal and fenestral limestone, light-gray dolomicrite, and thin interbeds of light-olive-green shale. Uppermost part includes interbeds of cherty limestone, olive-green and maroon mudstone, and grayish-yellow dolomicrite.

Figure 9. Example of geologic unit descriptions within the metadata.

Layout

Because a paper map is required for both the STATEMAP contract and for GSA publication, and because the layout capabilities of Adobe Illustrator, are superior to those of ArcMap, the map is exported out of ArcMap as an .ai file, and the layout is constructed in Illustrator. This step, however, is necessary only if a paper product is generated.

For the digital layout in ArcMap as both .mxd and Published Map Files (PMF), the feature classes are added with annotation feature classes placed in a layer and the geologic units in another layer. All layers are symbolized using a customized style that is released with the database. For display purposes the geologic units (GeologyPolygons) layer is organized by geologic age-each geologic age is added (same feature class added multiple times only for symbolization purposes) and symbolized separately (Figure 10A). Also, the cross section is provided as a hyperlink (as a PDF) in the .mxd and PMF files in the database package (Figure 10B).

A.

B.

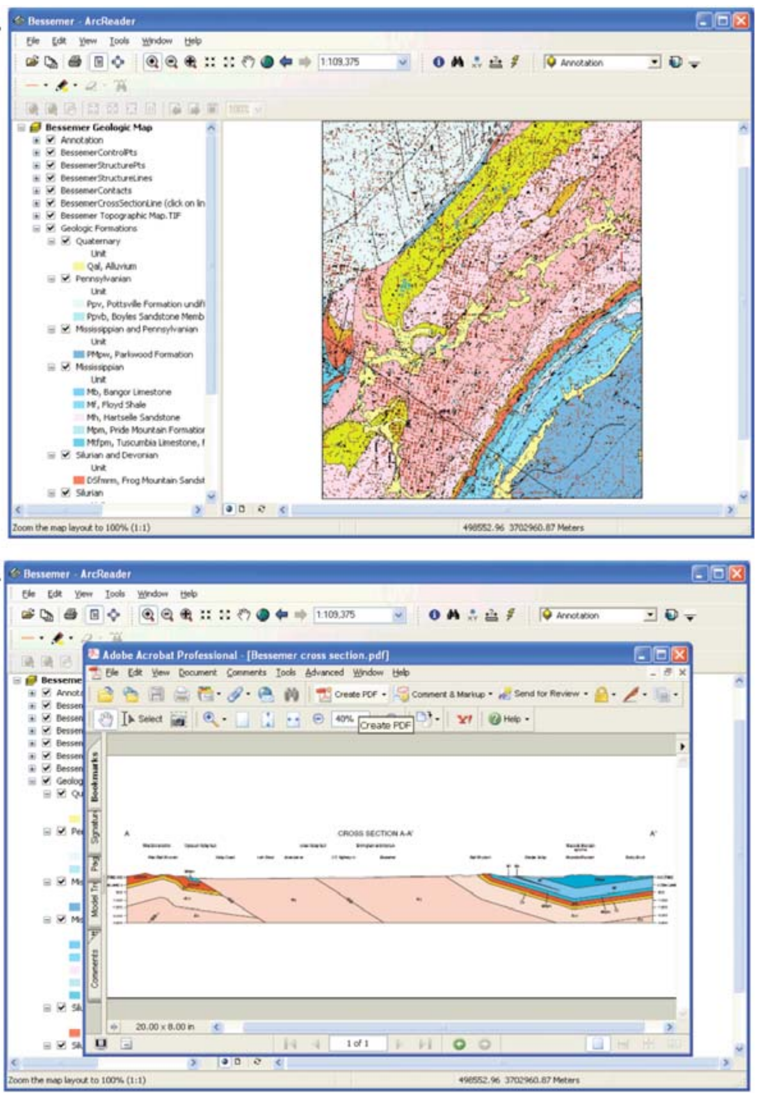

Figure 10. A. Layout of digital geologic map (same layout in both .mxd and PMF). B. View of cross section as it appears from hyperlink.

PUBLICATION OF MAP AND DATABASE

When the database and layout are ready for publication, a formal review process begins. The database goes through a digital review that includes examination of the database, metadata, and associated files. The map layout goes through an editorial review, and any changes that may affect the database are addressed. Once the review process is complete, final preparation of the publication package is undertaken. Metadata are imported back to the geodatabase, into the appropriate feature classes. A published map file package (PMF) is created, final PDFs of the layout are generated, and feature classes are exported to shapefiles for the shapefile package. The data are then posted to the GSA website (http://www.gsa.state.al.us/gsa/gis_data.aspx).

The digital data for GSA Quadrangle Series Maps consist of:

1. A Geodatabase package that contains geologic vector and table data stored as data objects within an ESRI personal geodatabase format, raster data stored as ESRI format DRG-TIFF, an ESRI map document for use with ArcGIS 9.3 (which allows full control of editing and rendering of the data sources), and an ESRI-published map document for use with Arc Reader, which allows viewing and querying of the source data along with metadata and an ArcGIS style for symbolizing the map.
2. A Shapefile package that contains shapefiles exported from the personal geodatabase and the same ESRI DRG-TIFF as in the Geodatabase package along with supporting files. This package does not contain annotation layers included in the Geodatabase package owing to software limitations.
3. A txt file with metadata for the entire database. (Metadata are also included within the GIS files.)
4. A PDF file of the map sheet and a PDF file of the cross section and map explanation.
5. A Readme file explaining data, construction of the map as it appears in the .mxd and .pmf, and location and placement of accessory files.

FUTURE

The recent purchase of a hand-held device for digital field-data collection has initiated a potential change in basic data-collection techniques. The evaluation of this device will influence mapping at the GSA. It is the hope of the GSA staff that a suitable and more efficient system will be devised using this hand-held device. This will eliminate a transcription step and hopefully allow for an expansion of database capabilities of the maps. Also, more immediate updates include the expansion of available hyperlinks, mostly in the form of field photographs added to the map databases.

The other major issue that needs to be addressed is the use of base maps. The scanned USGS topographic map is the base map currently used by the GSA. These base maps are not adequate, and although alternatives are being evaluated, none have yet proven cost-effective. Agency discussions on this matter have begun and suggestions include higher quality topographic bases, whether scanned by the GSA or from another source. The state of Alabama begun discussing the collection of LIDAR for the state, and this holds promise for the future. Improving the quality and integrity of the base maps will remain an issue until a satisfactory alternative is reached.